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ACADEMIA SINICA
Institute of Astronomy and Astrophysics

A ROTATION MEASURE GRADIENT ON THE M87 VLA JET

Towards evidence of helical magnetic fields
on kpc scales of the M87 jet

J. C. Algaba, K. Asada, M. Nakamura

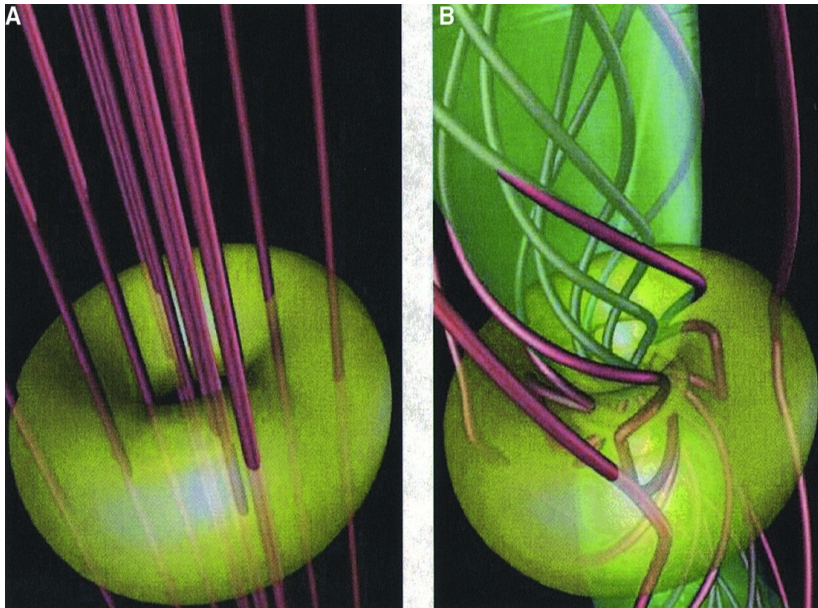
Walkthrough

- Introduction
- Rotation Measure in M87
- Polarization in M87
- A Helical Magnetic Field in M87?
- Conclusions

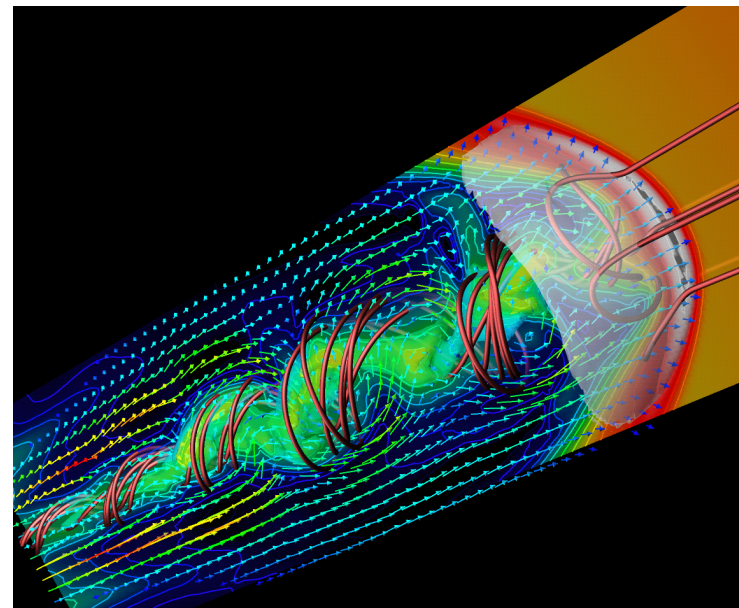
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- Helical B fields thought to exist in AGNs
 - Naturally arising from theoretical models

Meier+01



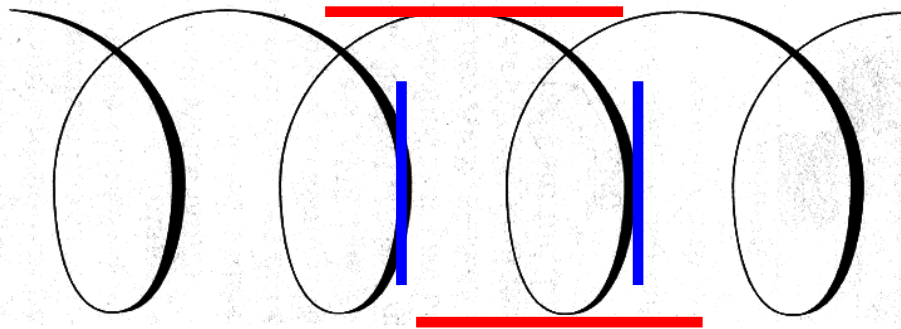
Nakamura+01



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 - Hints coming from observations
 - Linear polarization

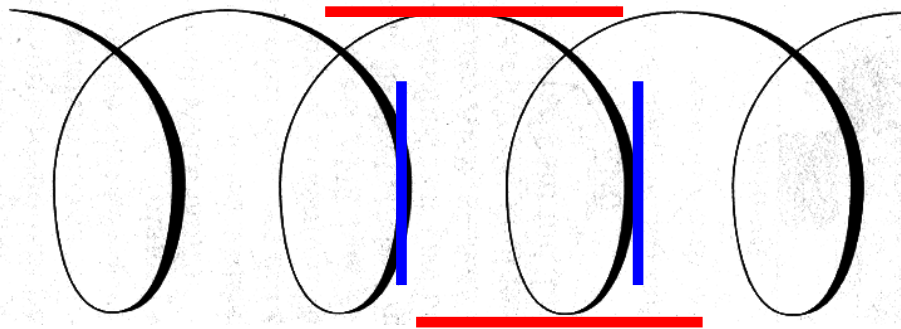
B



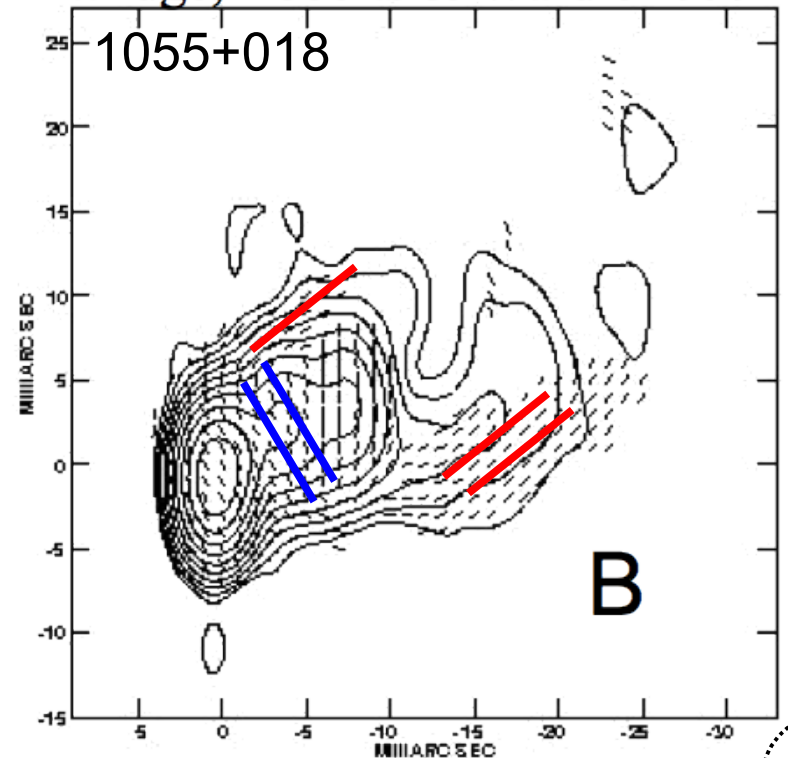
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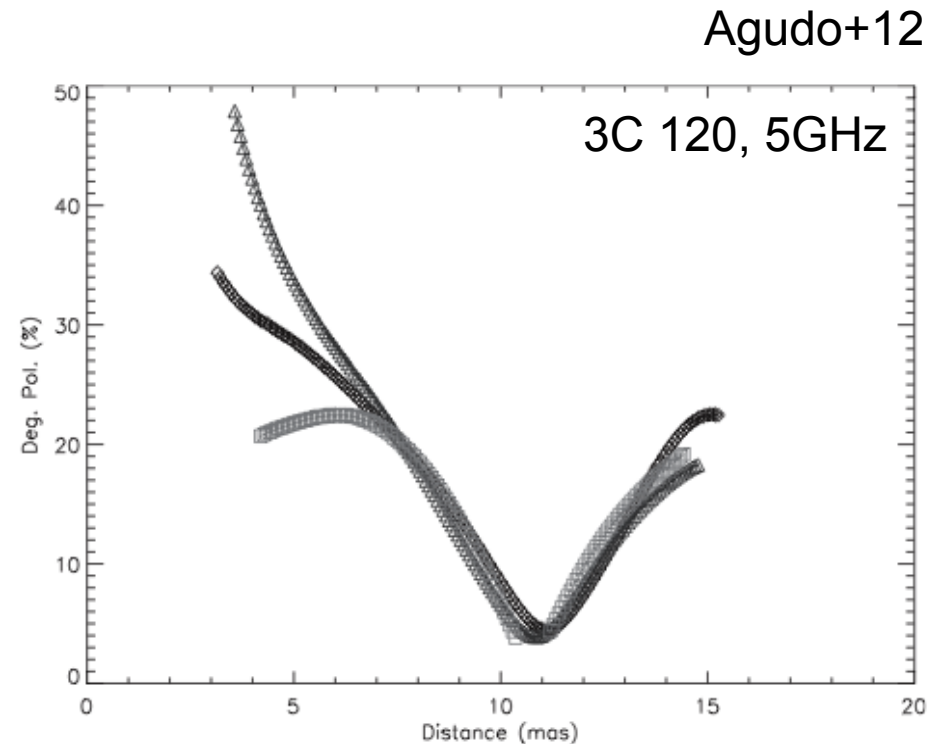


Attridge, Roberts & Wardle 1999



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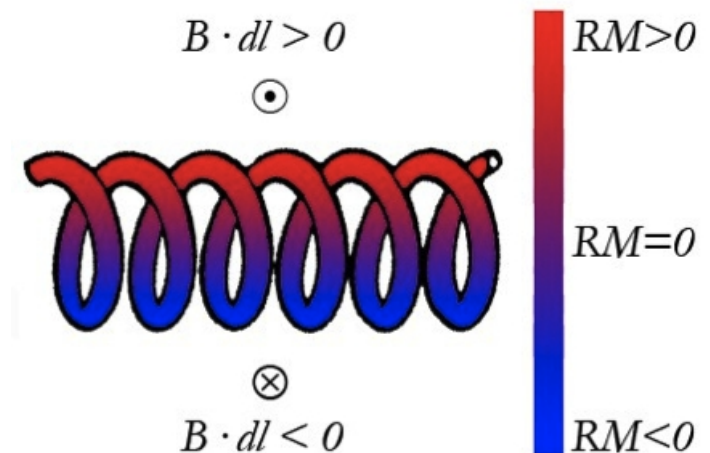


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$$\chi = \chi_0 + RM\lambda^2$$

$$RM \propto \int n_e B \cdot dl$$

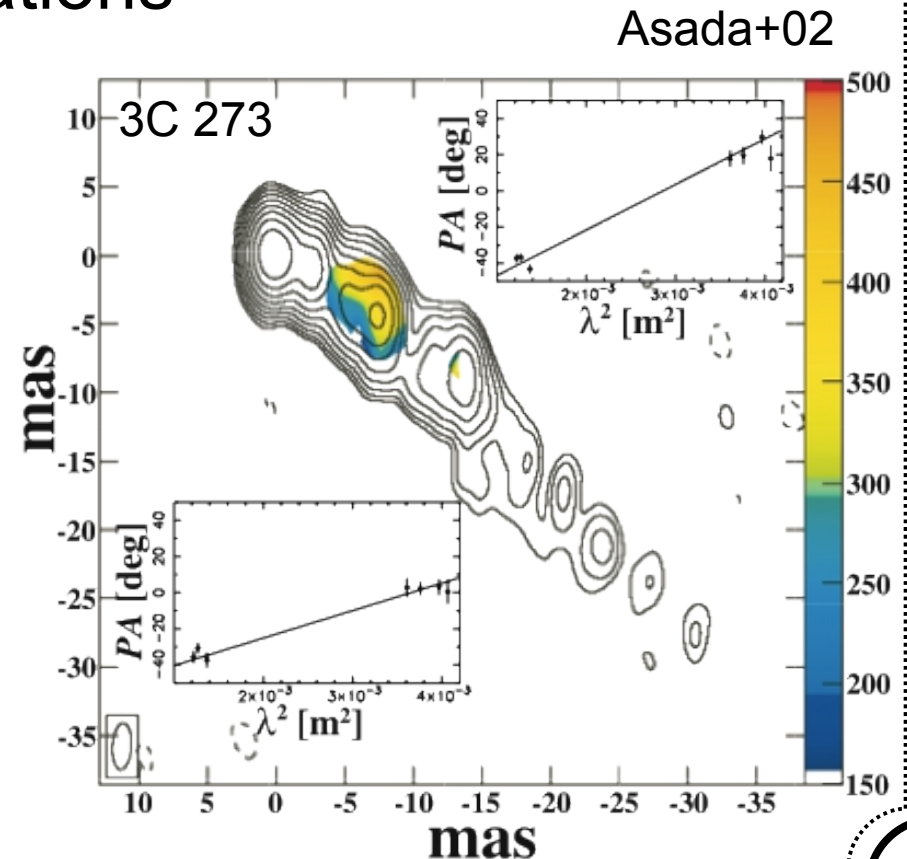


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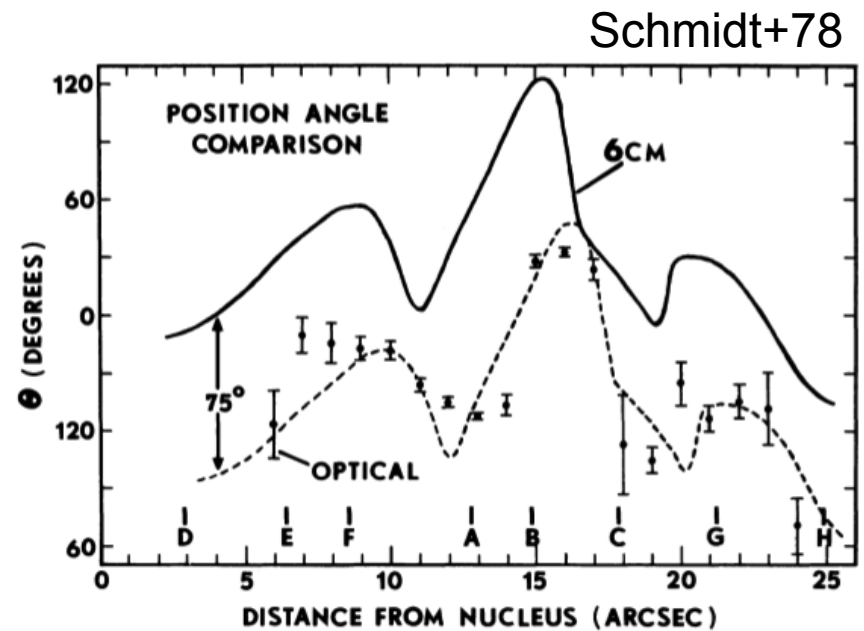


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- M87, paradigm of AGN jets
 - Does it also show indications of helical B fields?
 - What is the role of B fields in M87?

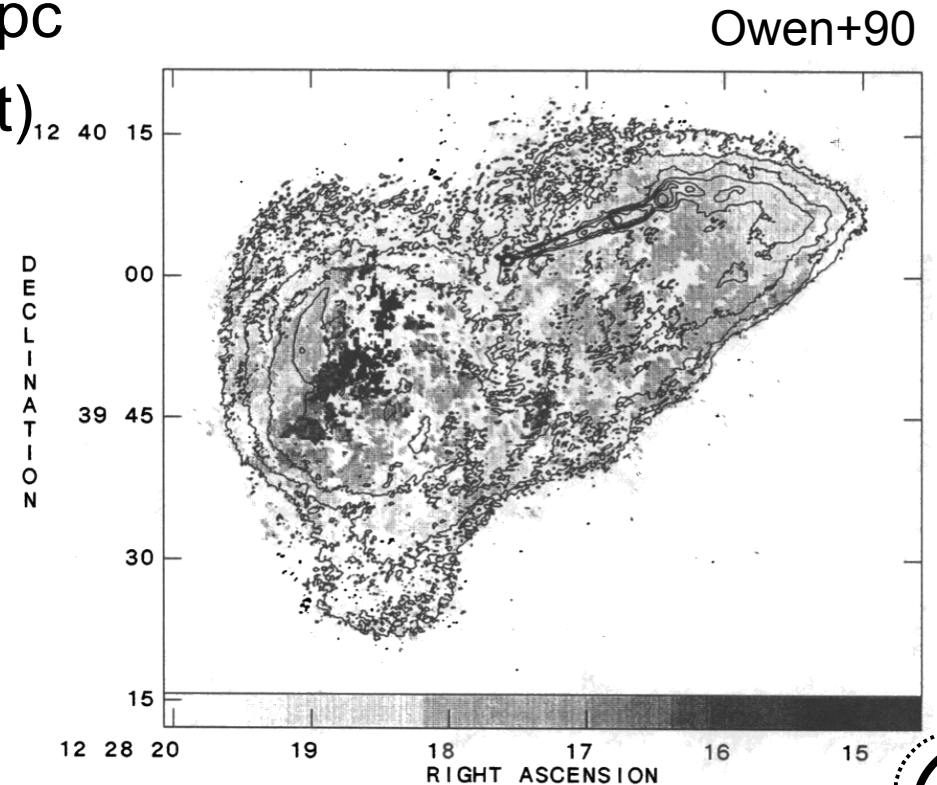
A Bit of History

- Comparison of angle at optical/6cm/1.3cm
 - Existence of Faraday rotation ($\geq 350\text{rad/m}^2$), external



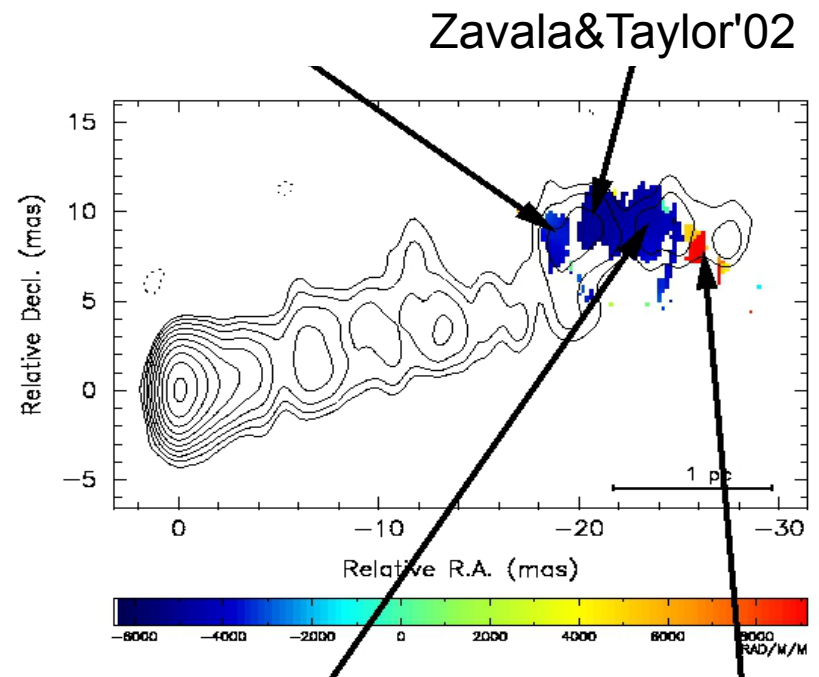
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 - Large ($\sim 2000\text{rad/m}^2$) on kpc
 - Low ($\sim 200\text{rad/m}^2$ in the jet)



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- VLBA RM Map
 - From -3000 to 9000rad/m^2 on sub-pc scales



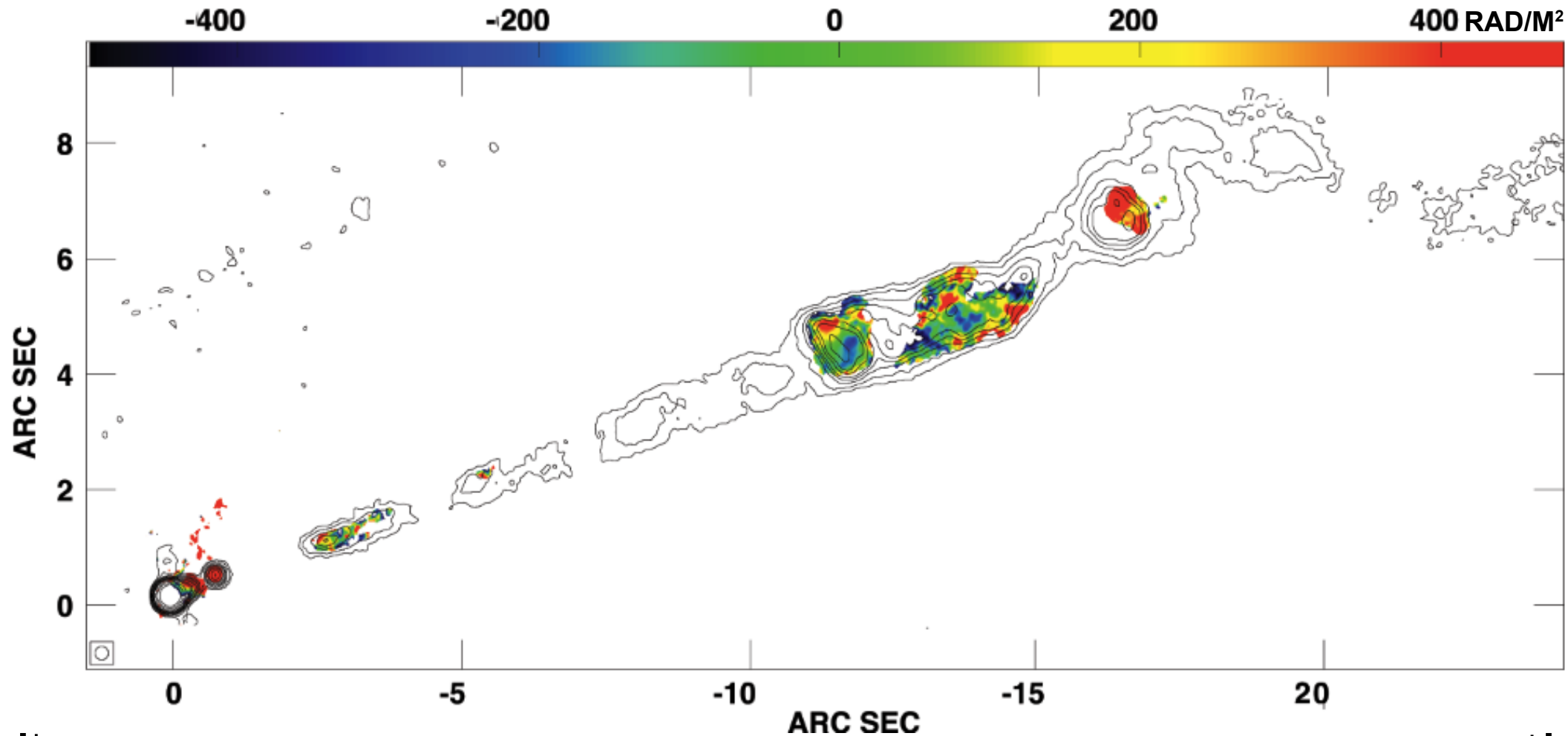
A Bit of History

- Strong polarization on optically thin kpc scales
 - e.g. Owen89, Owen90, Perlman99
- Differences between optical/radio polarization behaviour
 - e.g. Perlman+99
- Indications of higher fractional polarization on edge of the jet
 - e.g. Owen+89

A Bit of History

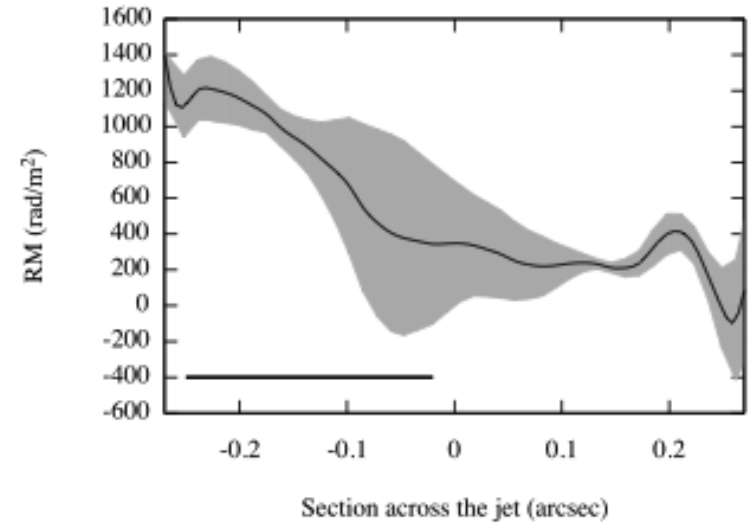
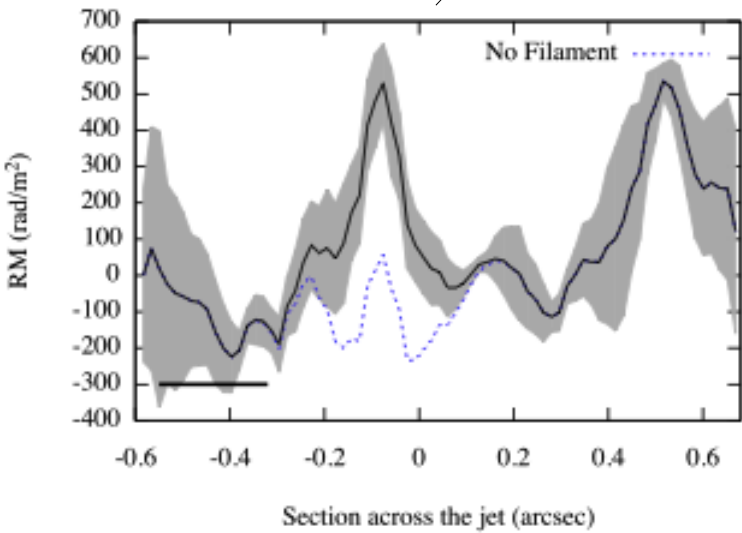
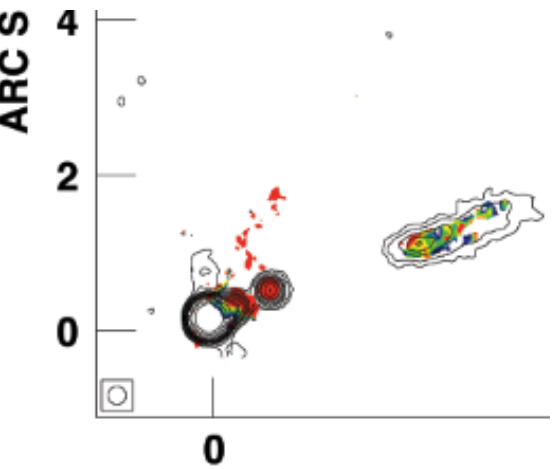
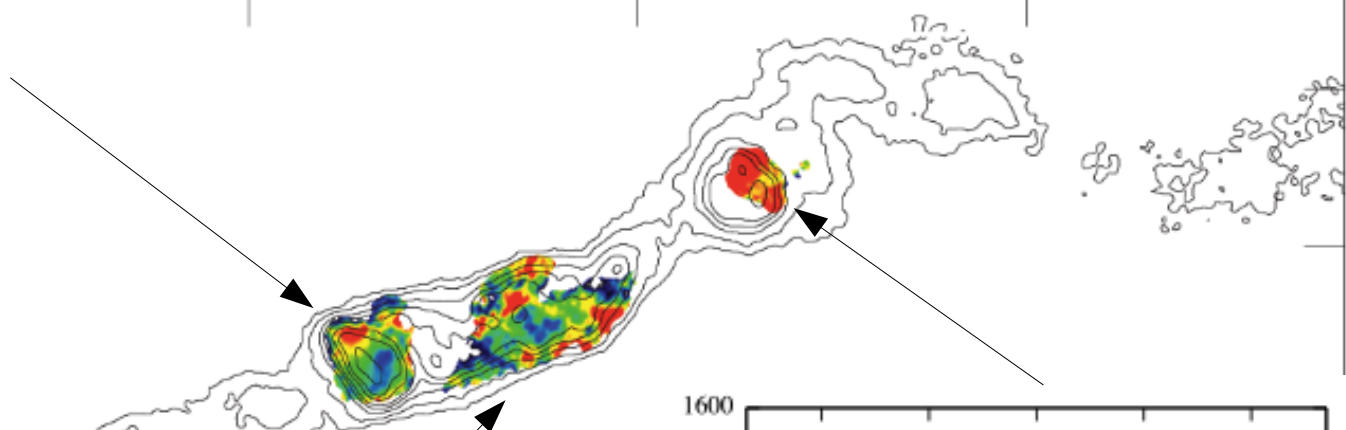
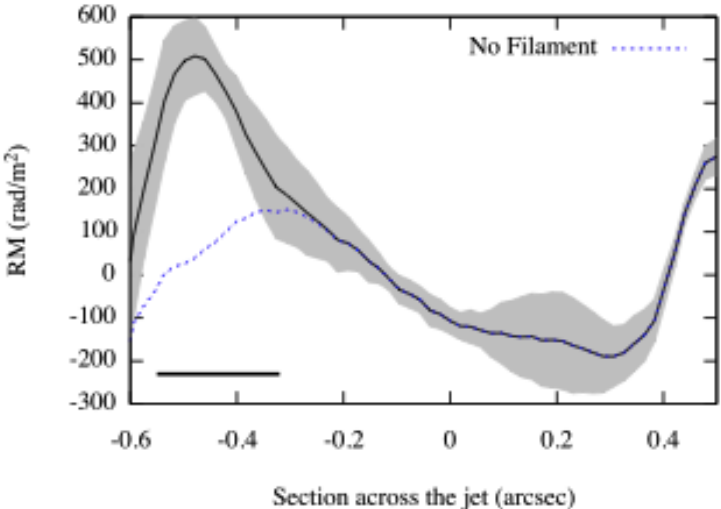
- Possibility of resolving across the jet
 - What is the structure of the RM?
 - Polarization cross-section across the jet
 - Quantify increase on edges
- Observations
 - VLA archival data 15, 22, 43 GHz
 - Stacked images from 2003-2005

RM in M87



- VLA 15+22+43 GHz

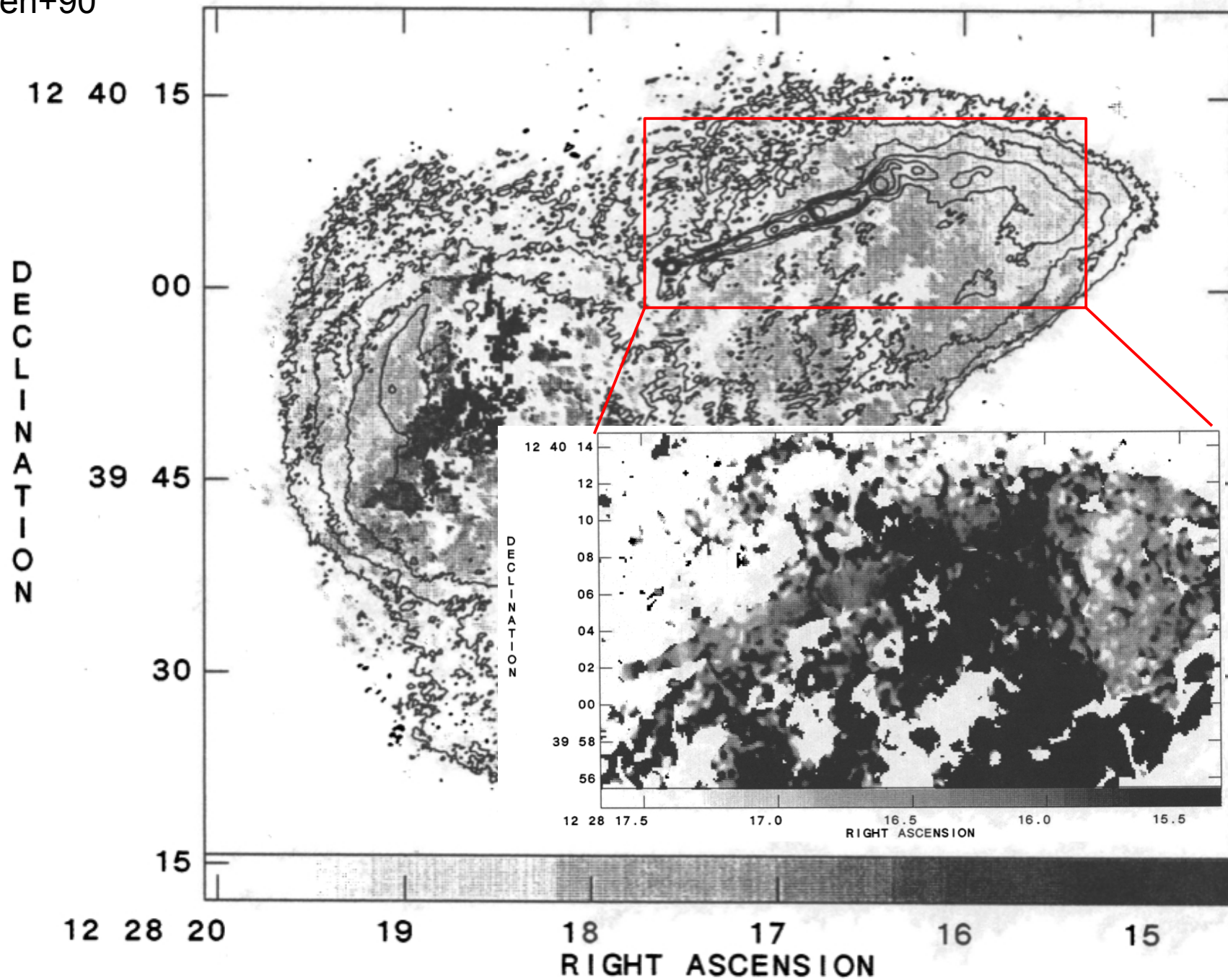
RM in M87



RM in M87

- Can this structure be due to a filament?
 - No total intensity counterpart
 - No feature from external Faraday screen (lobes) matching in structure or value (Owen+90)
 - Offset of the RM due to poloidal component compatible with viewing angle $\theta \sim 15^\circ$
- RM gradient in knots A and C

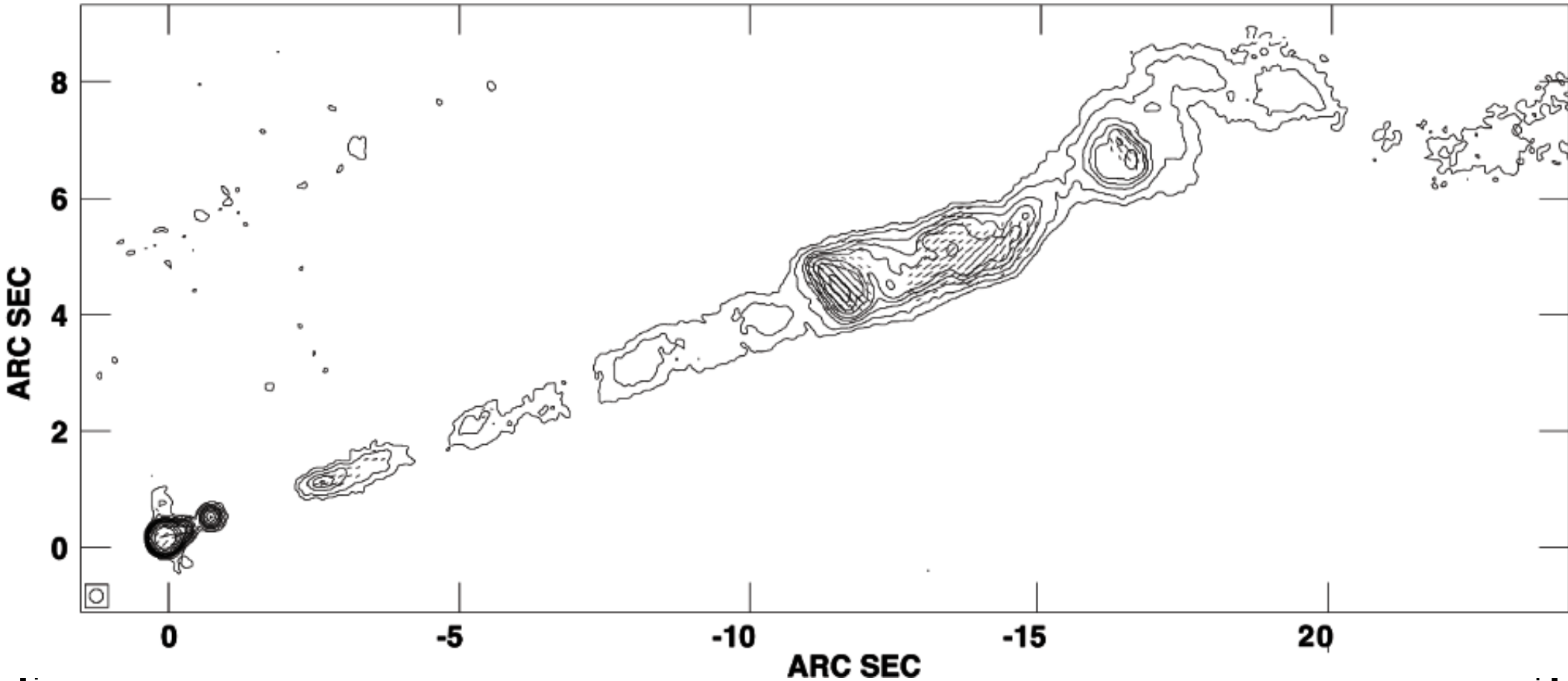
Owen+90



RM in M87

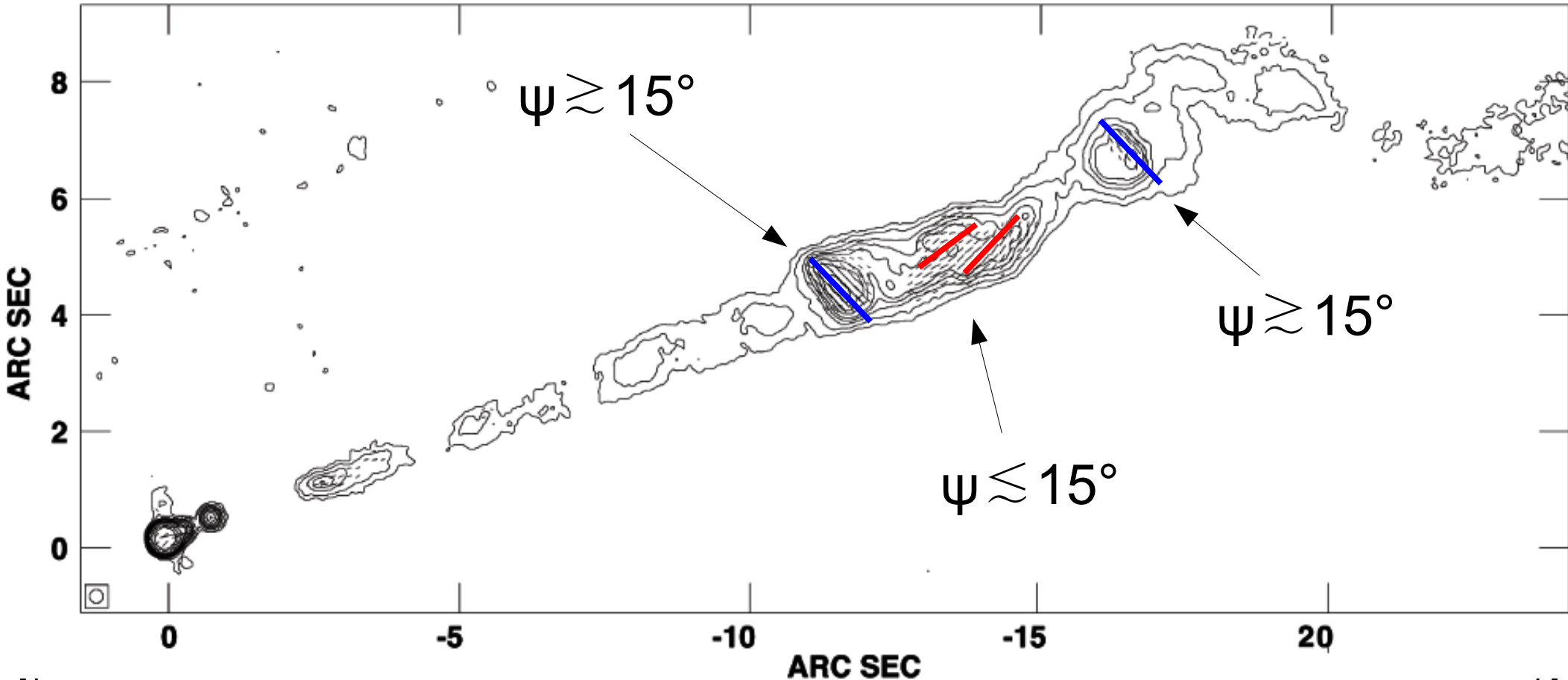
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Polarization in M87



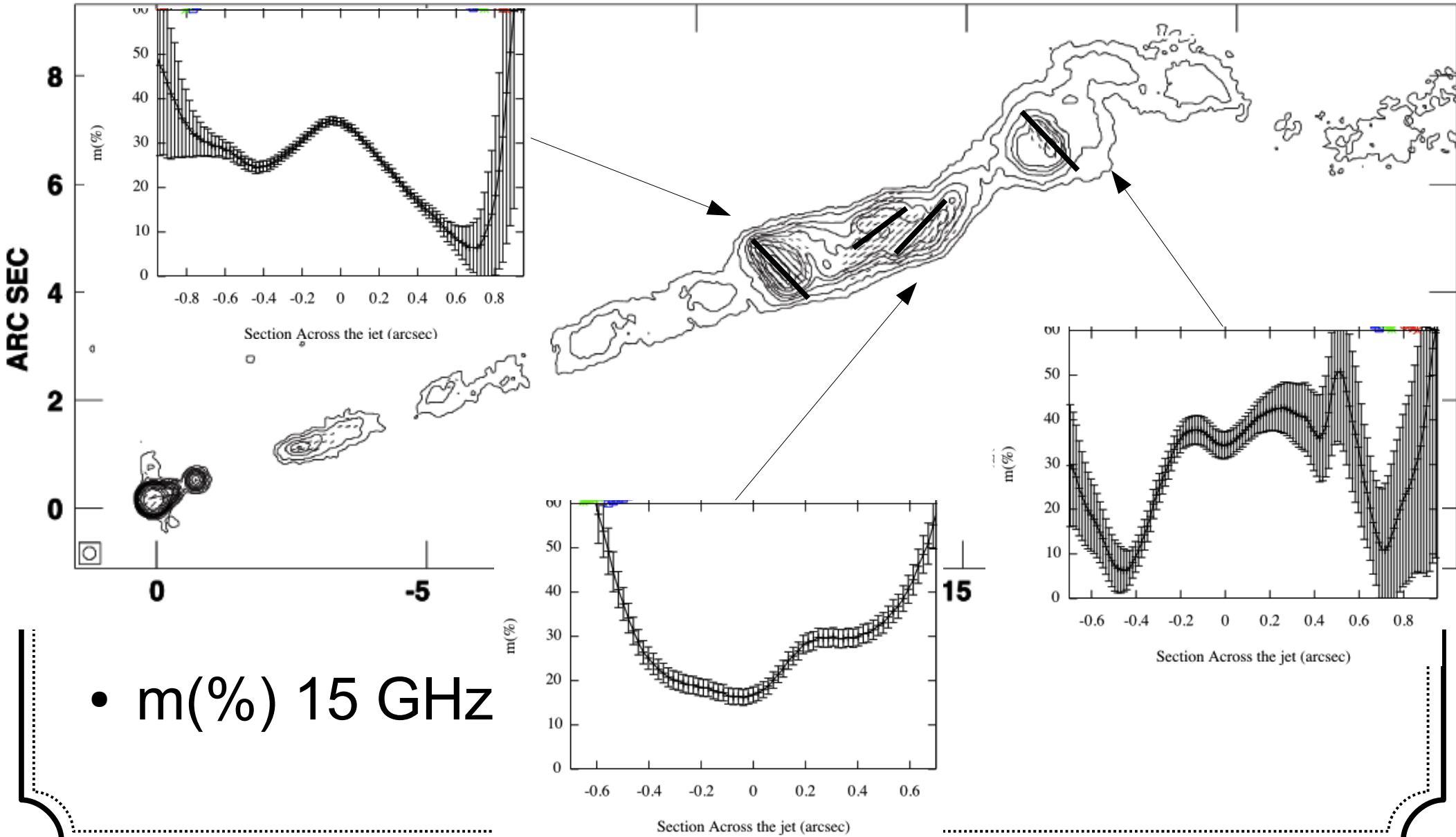
- RM corrected, B field

Polarization in M87

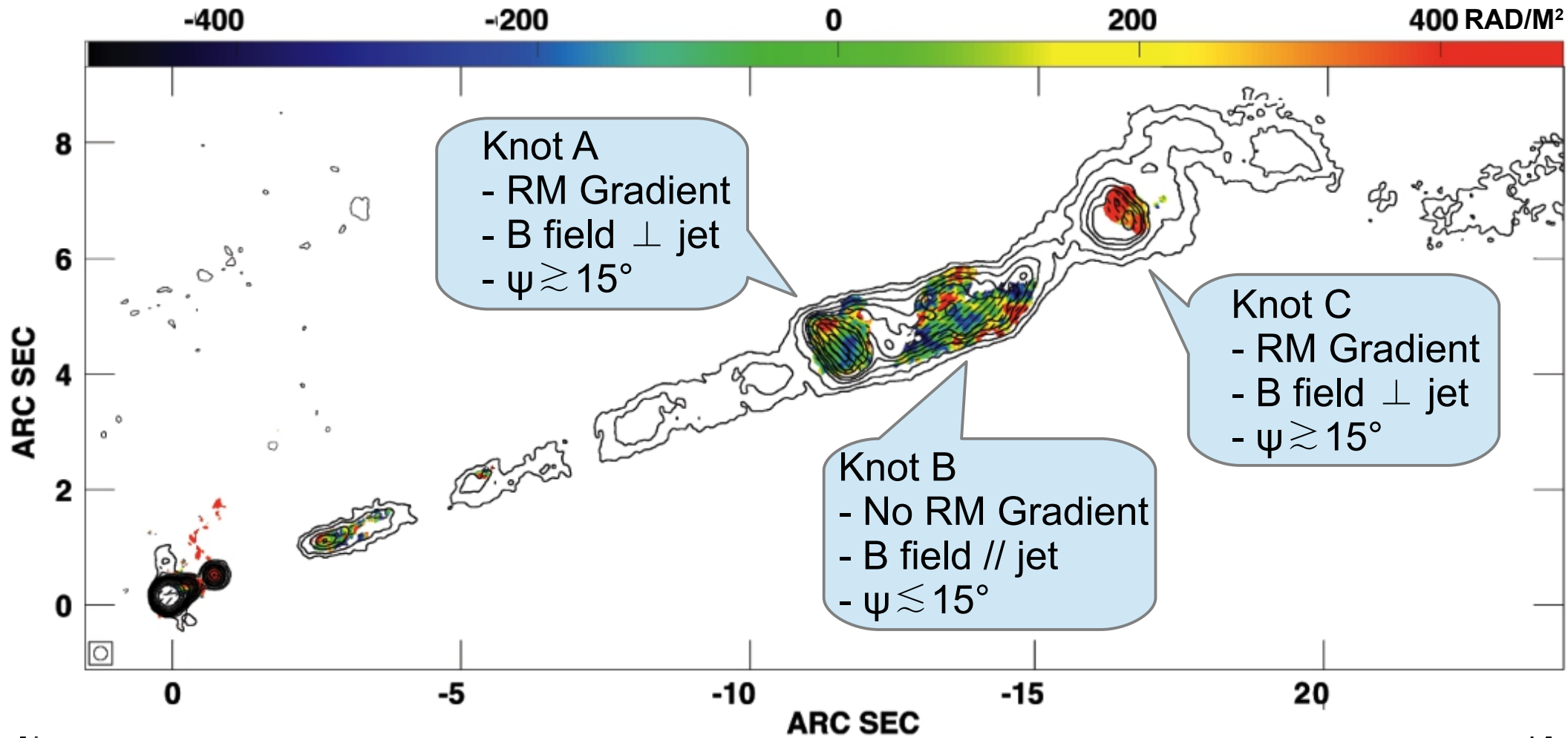


- Pitch angle $\Psi = \arctan B_\phi / B_z$

Polarization in M87

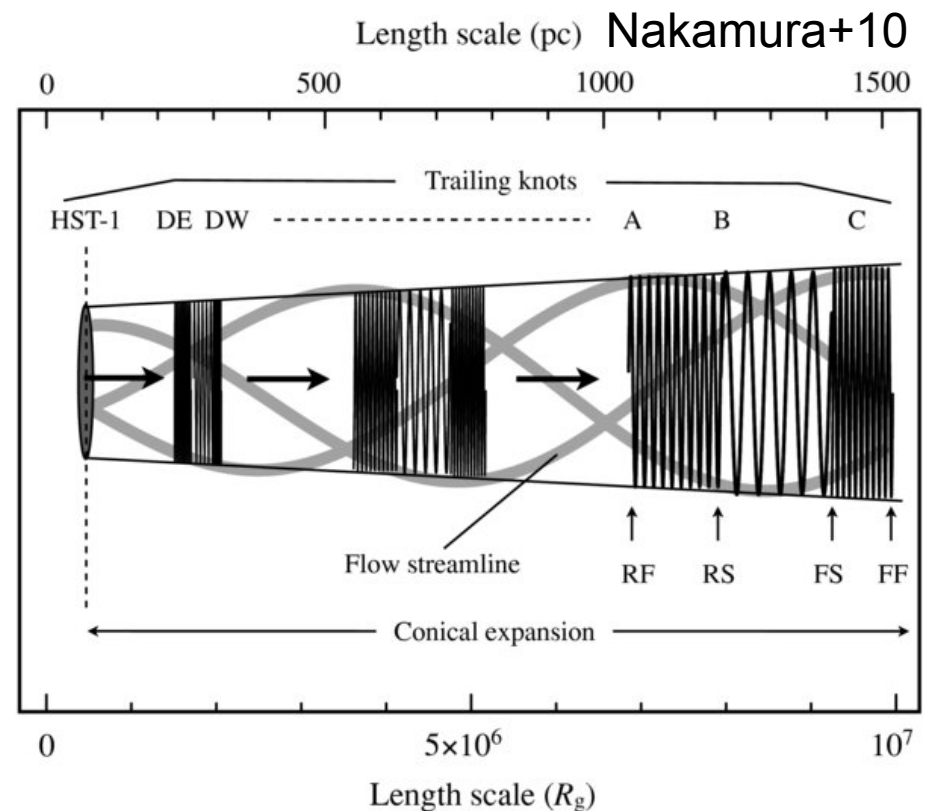


A Helical B-field in M87?



A Helical B-field in M87?

- MHD quad shock model
 - Trail of MHD quad shocks generated in HST1
 - Knots A, C forward/reverse MHD fast modes
 - Knot B post-shocked kink region, CDI(Nakamura&Meier04)

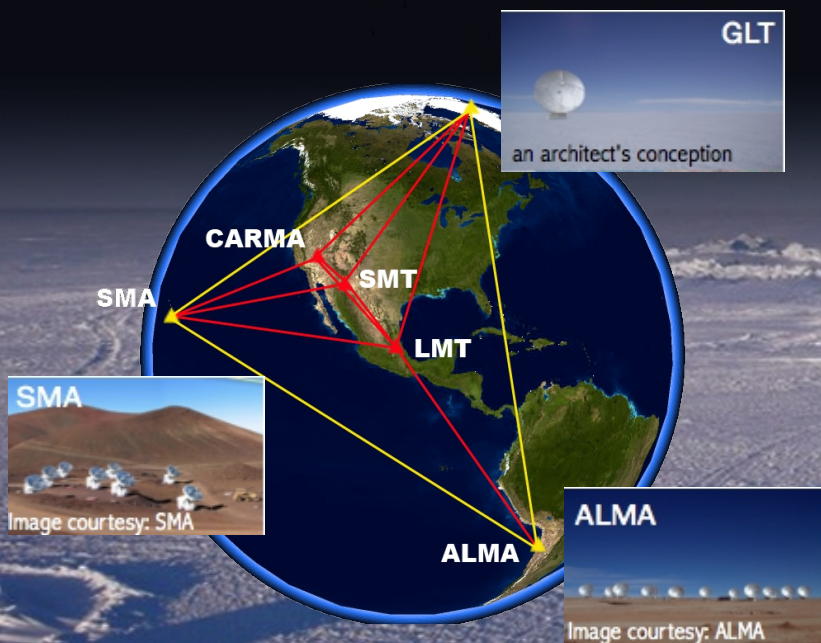


Conclusions

- Results pointing towards helical B field
 - Polarization direction along/across the jet
 - Increase of polarization on the edges of the jet
 - RM gradient across the jet when higher pitch angle
- Knots A, C shocks with tightly wound B field
 - In agreement with Nakamura+10 model.
- B fields play an important role even at kpc scales, far from SMBH

The Greenland Telescope Project

- **Main Goal: Direct Observation of the black hole shadow**
 - Combine with other sub-mm facilities (ALMA, SMA,...)
 - Largest resolution ever (baseline $\sim 8000+$ km, 230 GHz $\rightarrow \sim 20\mu\text{s}$)
- **Other Science Projects**
 - Sub-mm VLBI
 - Single dish science up to THz



See poster #11!
Get a free leaflet!



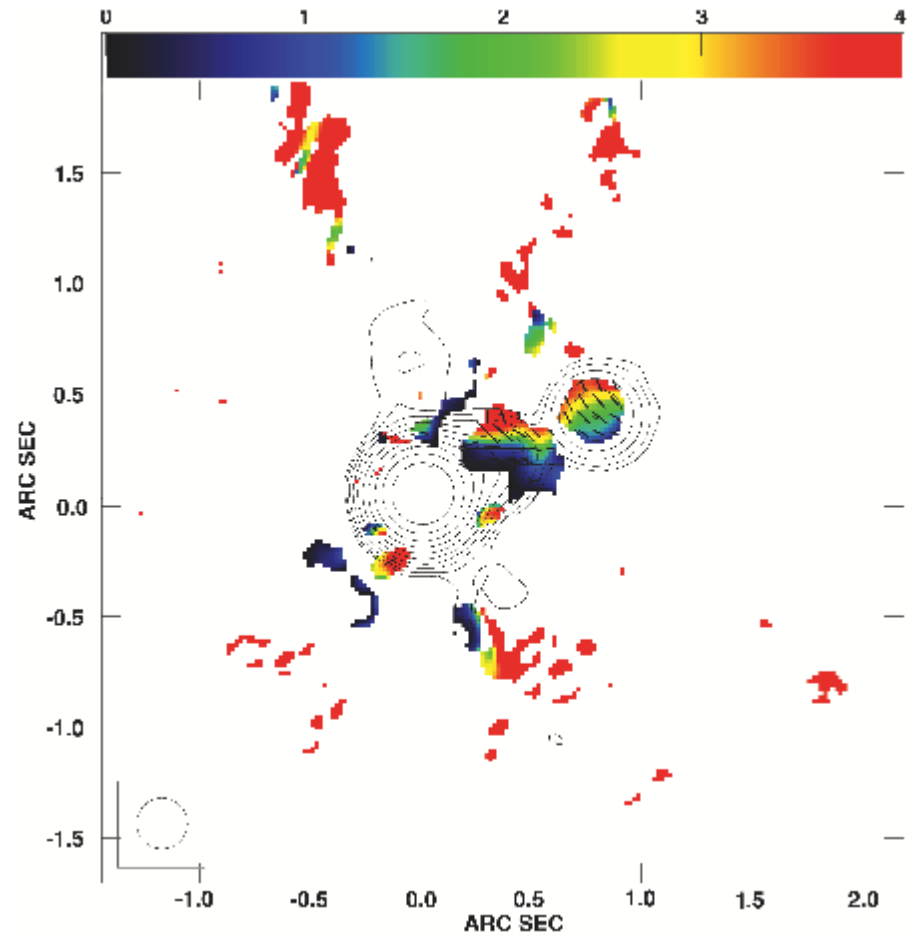
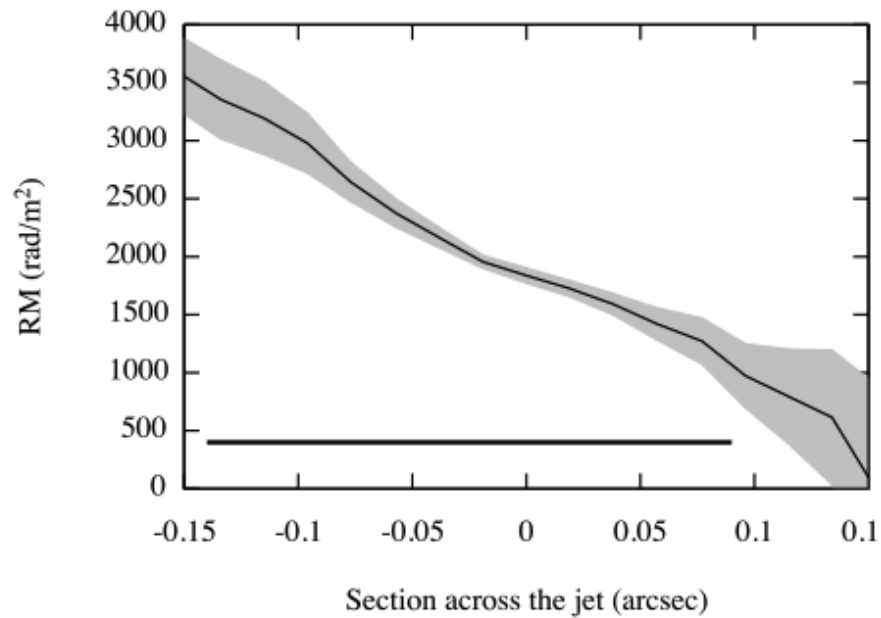


Thanks

Scratch Slides

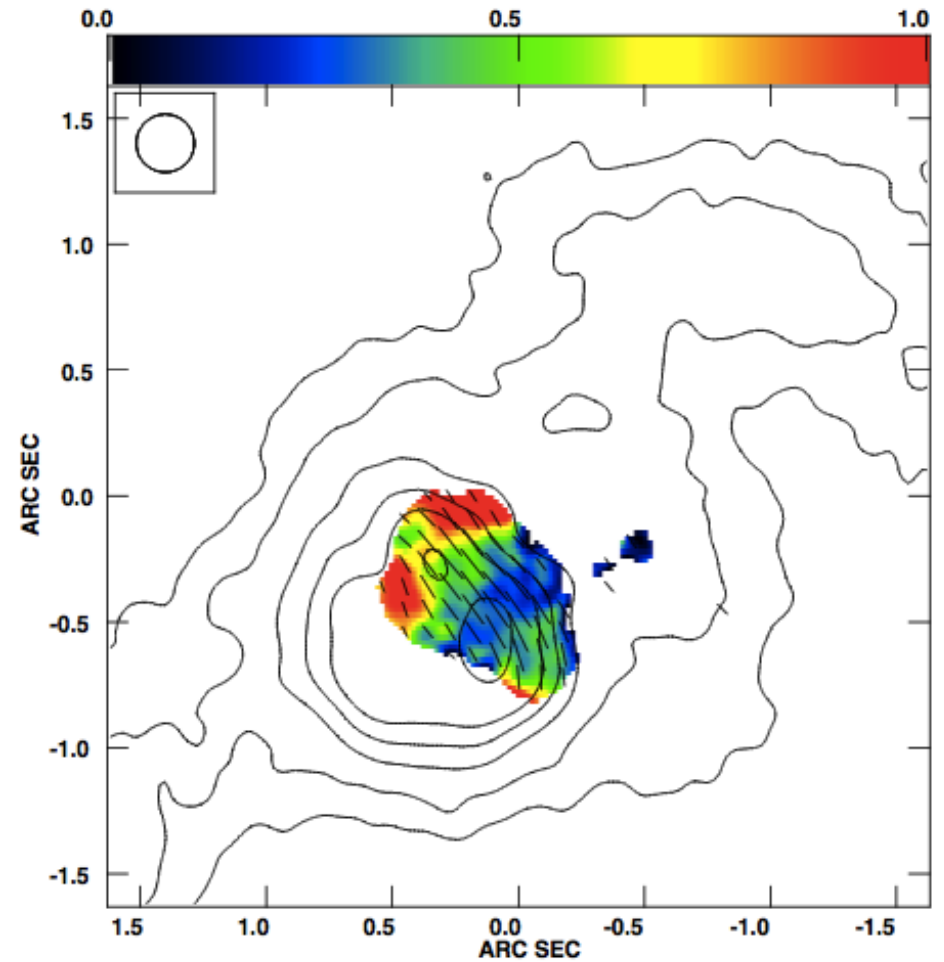
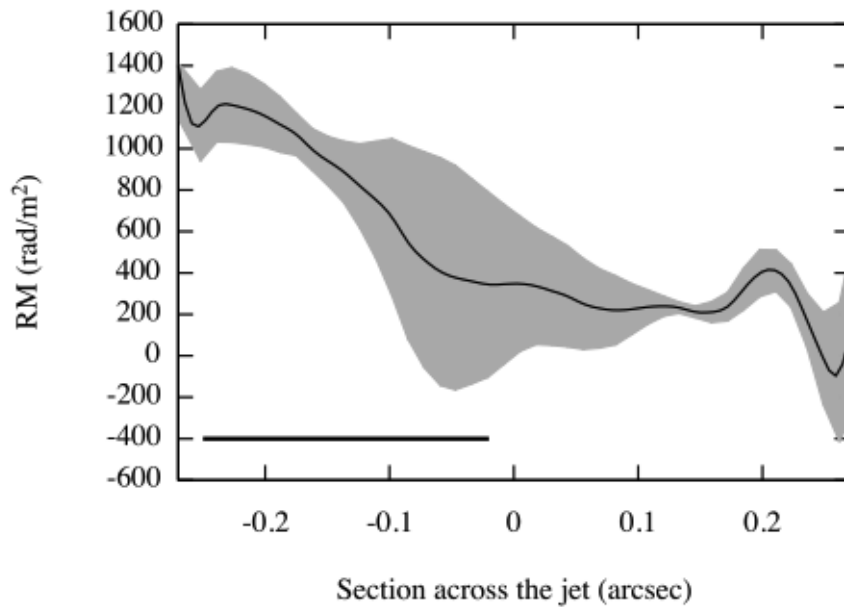
RM HST-1

- HST1



RM Knot C

- Knot C



Fractional Polarization

- Along jet

